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PROCEDURE FOR TESTING SYNTHETIC-FI3ER CABLES FOR FLEXING FATIGUE UNDER LOAD

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I. INTRODUCTION

One of the vital structures in a tethered balloon system is the tether. Generally, the tether mass is the largest single load on the balloon. Selection of a tether is therefore a fundamentally important part of the system design.

Modern synthetic fibers have provided cordage material with strength/weight ratios higher than steel and so the use of synthetic-fiber for tether cables is commonplace because of their weight-effectiveness.

Although the properties of steel cable are well known and standardized, there are far less data on the synthetics. Further, while steel obeys the laws of classical mechanics, the synthetics do not, but have "stress-creep" behavior which is an important part of their performance characteristics. Temperature effects and jacket design are also to be considered. The technology of synthetic fibers is relatively new and development activity has resulted in many important products. Polyamide (Nylon (r)) displaced lower strength materials and for many applications was, itself, displaced by terephthalate polyester (Dacron (r)). Most recently a new material known as Kevlar-29 has been developed which has a dramatically higher strength/weight ratio than any synthetic and all steel alloys.

Because of their lower modulus of elasticity and greater elongation, internal properties of synthetic cables are more important than those of steel rope. Prior to adoption for tether use, cables of new material should be tested to the degree required to establish the suitability of the basic material and of the cable construction to the requirements of, and service conditions to be encountered in balloon tether application.

II. PURPOSE

Since the balloon tether is usually run around a sheave (pulley) while it is under a tension load, an important secondary property of a balloon tether is freedom from deterioration of strength and of service-life as a result of passage over a sheave while loaded.

This test is designed to verify the integrity of balloon tether cable when subjected to repeated passage over a sheave while loaded in tension.

The test geometry is intended to be constructively simulative of the physical circumstances which prevail during the use of the cable as a balloon tether except that the test conditions are relatively more severe with respect to load and sheave diameter.

III. TEST DESIGN

Since there are no definitions or standards of performance to which to work, the alternative is to effectively simulate the physical geometry as to types of induced stress, to increase the load past natural, in-the-field, values, and carry the cycling to an arbitrarily larger number of cycles than would be experienced during one flight. If, after some large number of loaded cycles, no failure has occurred, the peak high value load should be increased, and another set of cycles performed. After a study of balloon tether tension records from flight tests, it has been decided that the fluctuating load should be simulated by alternating between two values of tension, (derived as percentages of ultimate). The sheave around which the cable is pulled should be positioned near the pulled-end so that advantage is taken of the elongation of the cable to produce most rotation of the sheave.

IV. TEST APPARATUS

The accompanying sketch is largely self-explanatory. The load cell is placed at the remote, fixed-end of the cable so that its movement with the stretching of the cable is zero. The hydraulic actuating cylinder and the hydraulic power supply must be capable of producing the tension required by the test. As illustrated the system is manually operated. Thus the tension indicator should be situated close to the hydraulics control panel. A pressure-operated, high-limit bypass valve permits initial setting of the maximum value of tension, independent of accumulating "permanent" elongation of the cable. The automatic limit feature reduces operator fatigue, ensures higher accuracy and promotes safety.

It is important that the sheave groove be sized to the diameter of the cable to be tested. Tolerance should be on the plus side. The groove should be circular in cross section to its diameter. It should be flared outwardly beyond this point although a small parallel sided region is tolerable. The groove should be as smooth as possible short of a specular finish. Buffing is not required.

All cable findings, such as thimbles, shackles, links, etc., should be of the heavy-duty type. Devices coming into contact with the line must be free of burrs and any other rough spots. A fitting which is acceptable for steel wire rope may be too poorly-finished for use with synthetic cable.

V. TEST PROCEDURE

A length of cable to be tested should be cut and eye spliced at both ends according to the procedure for flying cable as currently practiced. The length should be sufficient that elongation from minimum to maximum tension is sufficient to cause more than 180° rotation of the sheave.

(Maximum elongation values, approximately, are Polyester 9%, Kevlar 3%.) With the cable sample installed on the machine and at the tail block, the tension-measuring equipment calibrated, and the hydraulic power unit warmed-up, the test is begun with the initial application of tension. Care should be taken to insure that the cable reeves through the sheave correctly. It is advisable for this reason to apply tension gradually.

The performance of the test is now begun and it consists of running the tension of the cable, up and down, between two values of tension. To best simulate adverse practical values of tension, the cycling limits should be 30% of ultimate and 70% of ultimate.

If a large number of cycles have not failed the cable, the test should continue with a higher upper tension limit. A suggested set of conditions is 30% to 70%, 1000 cycles; 30% to 80%, 1000 cycles; 30% to 90%, 1000 cycles, and so on.

VI. DISCUSSION

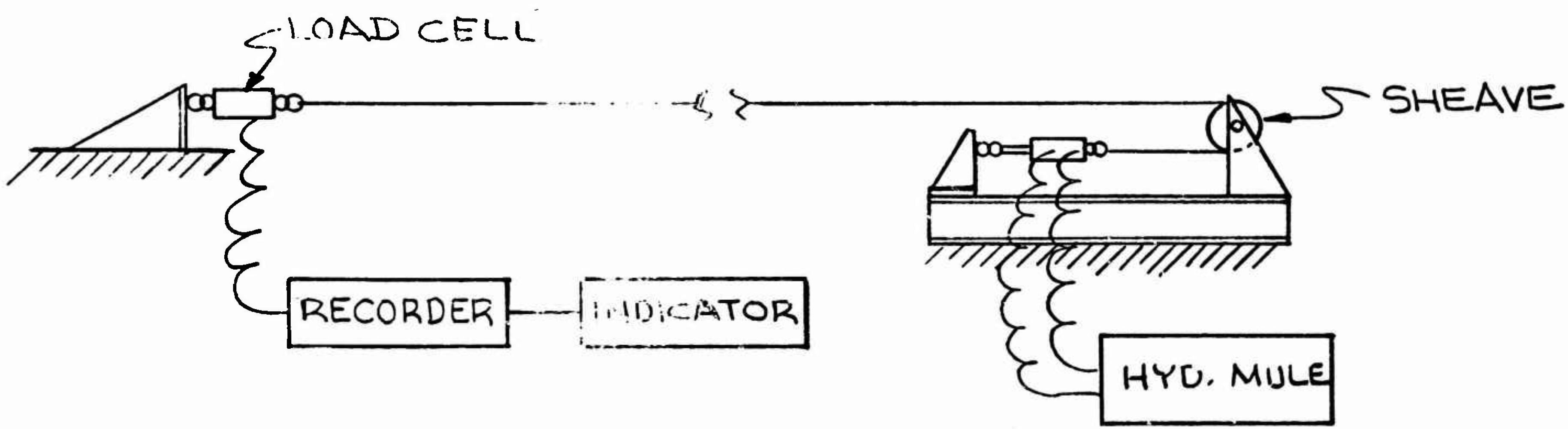
Since this type of test has not been previously performed, the numerical test conditions, above, are somewhat arbitrary. The value of 30% of ultimate as the lower tension limit is representative of the highest normal-flight tether-tension observed for the cable and balloon now being flown. The upper limit is chosen as a safe maximum for flight on a short-term stress exposures and, although conservatively low, it has never been reached in flight operations. The 1000 cycle duration was chosen as a number of stress peaks which is well beyond what could be reasonably expected in an 8 hour flight.

Experience in testing is expected to result in reconsideration of the test parameter values, and possibly in changes thereto. It is expected, for instance, that should the test-cable not fail in the 30-70 run before 1000 cycles, there would be justification for shortening the number to, say, 500 cycles per set.

The test is not intended as a quality assurance method. Its purpose is to discover any failure mechanism peculiar to, and induced by high longitudinal stress in combination with radial stress. Such phenomena as inter-fiber friction and differential yarn tension are produced by the test and may or may not be important in establishing cable safe working maxima.

From the foregoing it is seen that this test is rather like a type-evaluation of the material and of the cable structure. There appears no need to run a series of samples unless gross anomalies become evident.

It is expected that various cable types will be tested. The criteria of percent of ultimate will provide a useful and satisfactory basis for comparison. It should therefore be unnecessary to test more than one (size) sample of any particular material and construction.



SCHEMATIC

TETHER CABLE LOAD-FATIGUE TEST